DFE Upgrade Backplane Specification
Safety Addendum 6 May 2004
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Introduction

The DFE Upgrade Backplane Specification states that the backplane will be constructed without the use of bus bars. Rather, internal copper planes will deliver power to each slot. This raises some concern about the safety of the backplane, especially in regard to the Fermilab electrical design parameter which states that the current density shall not exceed 1000A/ in^2 in any of the power distribution hardware. In some cases this parameter is exceeded, but justification is provided in these cases.

Current Densities

Bulk Supply to the Backplane

These leads will be fused at 20A at the bulk supply. The power supply leads will be larger than 14 AWG.

Lug to Power Tap

Two power taps (ERNI 114194 or equivalent) will be used for the +48V and another two will be used for the +48VRTN. According to the ERNI literature [1], each power tap is rated for 40A @ 20C, and is de-rated to 24A @ 70C, per specification IEC60512 test 5b.

The lug to power tap surface area measures approximately 7x11mm, or 1.2×10^{-2} in^2 so assuming 20A is flowing through two power taps, the current density is 840 A/ in^2. A small copper bus bar will be installed between the two power taps to insure that *both* taps are connected the bulk supply cabling.

Power Tap Pin to Backplane

Each power tap connector has ten press-fit pins. The power taps are pressed into plated through holes in the backplane; they will not be soldered in and thermal relief patterns will not be used. Assuming that the backplane uses 1oz copper (thickness 1.4 mil) for the internal plane layer, the contact area per pin is:

(6.28)(0.5mm)(1.4mil) = 1.7×10^{-4} in^2 per pin. If two power taps are used, the total surface area is 3.4×10^{-3} in^2. A total of 20A flowing through these two power taps yields a current density of 5780 A/in^2, which exceeds the design guideline.

However, it should be noted that these current densities are present only in a thin cross section and that the metal area available for heat dissipation is much larger than the cross sectional area in which the heat is generated.

If one “unrolls” the cylindrical cross section it becomes equivalent to an internal PCB trace 123 mils wide. According to the IPC-D-275 specification, a 1oz 125 mil wide internal trace can handle 3A at +10°C temperature rise. In this application only 1A will flow through each pin, resulting in an estimated temperature rise of ~5°C.

Power Plane

The cross sectional area of the 1oz Cu backplane power plane is approximately 9” x 1.4mil = 0.126 in^2, which leads to a maximum current density of 1587 A/in^2, which exceeds the design guideline.

However, if one considers the backplane to be a 9” wide 1oz Cu internal trace, the IPC-D-275 and IPC-2221 specifications [2] can be extrapolated out as follows:

$\text{Area} = [\text{Max\_Current} / (k*(\text{temp\_rise}^{b}))]^{1/c}$
$\text{Trace\_Width} = \text{Area}/(\text{Thickness}*1.378)$

For IPC-D-275 internal layers: k = 0.0150, b = 0.5453, c = 0.7349.   Setting Max_Current = 20A, temp_rise=1°C, thickness = 1.4mil, the minimum Trace_Width is calculated to be 9215 mils. In other words, under full load this backplane will experience a temperature rise of ~1°C.

Hard Metric Connector Pin

Each slot will be individually fused at 2A. The +48V and +48VRTN are supplied through two pins each. These are Hard Metric (IEC-61076-4-101) pins which have a maximum resistance of 20 mΩ. All pins are press fit into a 0.6mm plated through hole. Thermal reliefs will not be used.

Assuming the backplane is 1oz copper, the plane to through-hole surface area is:

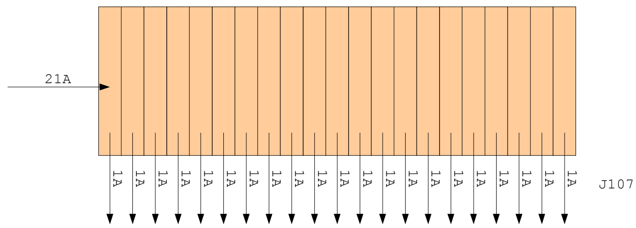
$(6.28)(0.3mm)(1.4mil) = 1.0 \times 10^{-4}\ in^2$ per pin.

Assuming that 2A is passing through two plated through holes the maximum current density is 9629 A/ in^2. Again, it should be noted that this is an extremely small cross sectional area, and any heat generated here will dissipate into the solid copper plane.

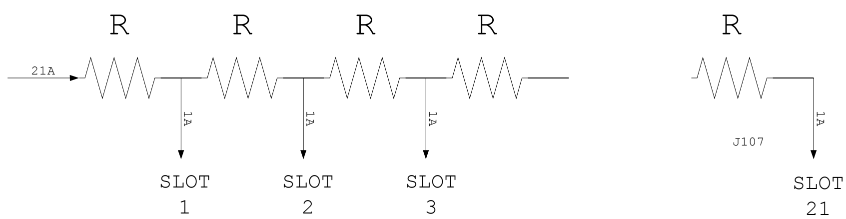
This cylindrical cross section is equivalent to an internal 1oz copper trace 75 mils wide. The IPC-D-275 specification states that such a trace can supply 1.5A with at 10°C temperature rise. In this application each pin can supply a maximum of 1A, so the estimated temperature rise is ~5°C.

Voltage Drop and Power Dissipation on the Backplane

The backplane can be thought of as being a PCB trace 9” wide. Which can be modeled like this:



or in schematic form,



The value of R is calculated as:

R = ρ*l/a

Where ρ is the resistivity of copper, 0.6788 μΩ*in; l is the segment length, 0.8”, and a is the cross sectional area of the 9” x 0.0014 (1oz Cu) plane = 0.0126 in^2. The value for R is 43 μΩ.

Once the value for R is known, a straightforward spreadsheet calculation will determine the voltage drop and power dissipated in the copper plane:

slot	current (A)	voltage (V)	drop (V)	Power (W)
0	-21	48.000000	0.000000	
1	1	47.999095	0.000905	0.019006
2	1	47.998233	0.000862	0.017239
3	1	47.997414	0.000819	0.015559
4	1	47.996638	0.000776	0.013964
5	1	47.995906	0.000733	0.012455
6	1	47.995216	0.000690	0.011033
7	1	47.994570	0.000646	0.009697
8	1	47.993966	0.000603	0.008447
9	1	47.993406	0.000560	0.007284
10	1	47.992889	0.000517	0.006206
11	1	47.992415	0.000474	0.005215
12	1	47.991984	0.000431	0.004310
13	1	47.991596	0.000388	0.003491
14	1	47.991251	0.000345	0.002758
15	1	47.990949	0.000302	0.002112
16	1	47.990691	0.000259	0.001552
17	1	47.990475	0.000215	0.001077
18	1	47.990303	0.000172	0.000690
19	1	47.990174	0.000129	0.000388
20	1	47.990087	0.000086	0.000172
21	1	47.990044	0.000043	0.000043
		total power (W)		0.143

This is in fact the worst case condition: if any slot draws more current, the fuse on the bulk supply will blow; if any slot draws more than 2A, it's local fuse will blow.

Conclusion

The total heat generated in the backplane is a function of: resistance in the power planes, resistance of the power taps, and hard metric connector vias. Heat dissipated in the power planes is calculated as ~286mW.

While the current density flowing through the plane/through-hole interface exceeds the 1000A/in^2 specification, it should be noted that this cross section is small and the copper power planes will act as a heat sink. Furthermore, when these cross sectional areas are modeled as traces, the IPC-D-275 specification shows only a small (~5°C) temperature increase in these areas.

References

1. ERNI Hard Metric Catalog, available online at
http://www.erni.com/DB/literature/ermet.ssi

2. Brooks, Douglas, “Temperature Rise in PCB Traces”, available online at
http://www.ultracad.com